

### Carousel Mixer

The present invention concerns mixers for particulate matter, particularly powders.

Many types of mixers are currently available to mix particulate components and typically depend upon random movement of the particles in a single chamber to achieve the mixing, movement being stimulated by e.g. rotating the chamber or by a rotating mixing blade. However, due to the dependence on random particle movement mixing must continue for a prolonged period in order to provide a reasonable chance of the different particulate components being sufficiently mixed (for example it may be desirable for two random samples from the mixture to have at least a 90% or 95% probability of being samples from a completely mixed population). A further problem with this type of mixer is that of segregation; where components having particular characteristics (e.g. particle size) separate out from those having different characteristics. For such segregating powders mixed with a tumbling or a stirring action, it may not be possible to achieve an acceptable state of mix, even after a very long mixing time.

The need for prolonged mixing can also result in undesirable heating of the particulate components which can be a particular problem for materials having low melting or softening points. The use of a vigorous mixing action can also result in fracturing of the particulate components.

Mixers known in the art include those of JP 59-136125, JP 59-160521, DT 2518420, US 1401211 and US 4626104

The present invention overcomes the prior art disadvantages, providing mixing apparatus which cause the exponential mixing of matter placed in the apparatus, with a minimum of mechanical force being exerted upon the matter, thus preventing fracturing and heating of the matter to be mixed. The apparatus also provides the advantage of being able to mix additional batches of matter whilst a first batch is being mixed.

According to the present invention there is provided mixing apparatus comprising a plurality of vertically-arranged levels of mixing compartments, each level of mixing compartments comprising  $M^N$  compartments where  $M \geq 2$  and  $N \geq 2$ , each compartment having an openable bottom, each level of compartments being rotationally displaceable relative to the adjacent level or levels, and there being at least  $N+1$  levels of mixing compartments. The compartments may be angularly spaced, each compartment being disposed outwardly from a common origin, the centre of each compartment being equiangularly displaced from the centre of each adjacent compartment.

As will be seen from the example given below, mixing is a mechanically simple process, causing little possible heating or damage to the matter to be mixed. The mixing actually occurs as the matter passes from one level of compartments to the next, as well as being caused by the controlled rotation of the levels of compartments relative to one another (see below). The insignificant amount of interparticulate movement during carousel rotation and mass flow on discharge of the cells both minimise segregation. This means that once the matter has exited the first pair of levels of the apparatus, new matter to be mixed may be introduced to the first level. Thus the apparatus can not only mix in a single batch-like fashion, but can also be used to provide a continual mixing with the controlled addition of new matter as matter already in the apparatus is mixed.

In order to simplify the construction of the apparatus, the first and subsequent alternate levels may be in a fixed position, the second and subsequent alternate levels being moveable. Alternatively, the first and subsequent alternate levels may be moveable, the second and subsequent alternate levels being in a fixed position. As described below, this allows a central rod to move alternate levels of the apparatus to effect the mixing. This uniform movement of alternate levels of compartments is also acceptable for batch mixing.

An example of mixing apparatus is a carousel mixer comprising 4 levels of compartments. Each level may have  $2^3$  (8) compartments. The first and third levels may be movable relative to fixed position second and fourth levels. After three mixing cycles resulting in all the matter being collected in the compartments of the fourth (N+1) level, the matter is completely mixed, each of compartments 1-8 of the fourth level containing one eighth of the matter originally contained in each of compartments 1-8 of the first level. Additional levels of mixing compartments (for example another N levels) may be added to further mix the matter.

Subsequent to the final level of the apparatus there may be a collecting vessel into which the mixed matter is released.

For the continuous discharge of powder from the mixer, an additional "discharge" level (e.g. carousel) may be used. Discharging each of the compartments in sequence provides a semi-continuous output of mixed material. To make the output continuous and further improve the state of mix of the powder, the compartments in the discharge level may be sub-divided vertically into sub-compartments.

Also provided according to the present invention is a method of mixing matter, comprising the steps of:

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- i) placing the matter to be mixed in the first level of mixing compartments of mixing apparatus according to the present invention;
- ii) arranging the first level of mixing compartments relative to the mixing compartments of the level below such that upon emptying the compartments of the first level, the contents of each mixing compartment will be equally divided between the M adjacent mixing compartments below;
- iii) for each whole number X in the series 1 to M;
- iv) starting with compartment X, emptying the contents of it and each subsequent Mth compartment into the compartments of the level below;
- v) rotating the first and second levels relative to each other
- vi) repeating steps (iv) and (v) until  $X=M$  with the exception of step (v) when  $X=M$ ; and
- vii) repeating steps (iii) to (vi) for each subsequent level of compartments, and increasing the starting compartment of step (iv) each time until  $X=M$ , in which case the starting compartment of step (iv) should be decreased each time until  $X=1$ , in which case it should again be increased each time.

Where  $M=2$ , the rotation of step (v) comprises rotating the first level clockwise relative to the level below by  $(360/M) - (360/M^N)$  degrees, and at each repetition of step (vii), the subsequent rotation of step (v) should be in the same direction as previously.

Thus with apparatus having  $2^3$  compartments in each level, at step (iii) compartments 1,3,5 and 7 will be emptied together, and compartments 2,4,6 and 8 will be emptied together. Apparatus having  $3^3$  compartments in each level would result in compartments 1,4,7,10,13,16,19,22 and 25 being emptied together; compartments 2,5,8,11,14,17,20,23 and 26 being emptied together; and compartments 3,6,9,12,15,18,21,24 and 27 being emptied together.

The rotation of step (v) ensures that each compartment to be emptied will empty equally between two adjacent compartments in the level below.

The amount and direction of mixing in step (v) and the starting compartment X in step (iv) are selected to ensure that exponential mixing occurs. Thus with  $2^3$  compartments in each level, compartments 1,3,5 and 7 may be emptied, the level rotated by  $+135^\circ$  and compartments 2,4,6 and 8 emptied. At the next level, compartments 2,4,6 and 8 would be emptied, the level rotated by  $+135^\circ$  and compartments 1,3,5 and 7 emptied. At the next level, compartments 2,4,6 and 8 would be emptied, the level rotated by  $+135^\circ$  and compartments 1,3,5 and 7 emptied. The series of initial compartments emptied in each of the three steps is 1,2,2 and would continue 1,1,2,2,1,1 etc. if there were additional levels. It is possible for this series to be entered at any point and for it to result in the required exponential mixing. Similarly, with  $3^3$  compartments in each level, the series would be 1,2,3,3,2,1,1,2 etc. and it can also be entered at any point to effect the required exponential mixing (e.g. 2,1,1,2,3,3,2... etc.).

The method may comprise the additional step of releasing the mixed matter for collection.

The invention will be further apparent from the following description, with reference to the figures of the accompanying drawings, which show, by way of example only, one form of carousel mixing apparatus. Of the figures,

Figure 1 shows the construction of a carousel mixer and of the compartments of a single level of the mixer;

Figure 2 shows a mixing process; and

Figure 3 shows a bottom view (Figure 3a) and a view through a section A-A of a discharge carousel mechanism.

As can be seen from Figure 1, the apparatus comprises four levels (10, 20, 30, 40) of 2<sup>3</sup> compartments 50. Levels 2 and 4 (20, 40) are fixed in position, whilst levels 1 and 3 (10, 30) are connected to a central shaft 60 which can be rotated to effect movement of each level (10, 20, 30, 40) relative to the levels (10, 20, 30, 40) above and below it.

As the mixing proceeds at step 1, compartments 1,3,5 and 7 are emptied at level 1, the level rotated by +135° and compartments 2,4,6 and 8 emptied. At step 2, level 2 compartments 2,4,6 and 8 are emptied, level 3 rotated by -135° and compartments 1,3,5 and 7 emptied. At step 3, level 3 compartment 2,4,6 and 8 are emptied, level 3 rotated by -135° and compartments 1,3,5 and 7 emptied. This results in each of the compartments of level 4 containing one eighth of the original contents of each of compartments 1-8 of level 1.

As can be seen from the discharge carousel 100 of Figure 3, the compartment 110 is divided into sub-compartments 111-114 by dividing walls 120, 130,

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140. Linear actuator 150 is mounted on the outer wall of discharge carousel 100. Slidable rod 170 passes through hole 161 in outer wall 160 and is moveable back-and-forth by linear actuator 150. Dividing walls 120,130,140 comprise fixed upper sections 121, 131, 141 and hinged lower sections 122, 132, 142. Movement of rod 170 back-and-forth by actuator 150 causes the opening and closing of each of sub-compartments 111-114 in turn, providing a continual release of mixed matter.